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Optical Image Memory in Slow Surface States on Germanium Read Out by Acoustic Surface Waves

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Introduction An image scanner using separated medium acoustoelectric effect of Si and $LiNbO_3$ has been proposed,[1,2] and the acoustoelectric effect related to the slow surface states of germanium has been mentioned.[3] In the present paper it is described that the optical images can be stored on the surface of Ge and can be detected by the acoustoelectric effect. This optical image memory element utilizes the memory effect of the slow surface states[4-6] and the spatial resolution property of acoustic surface waves.

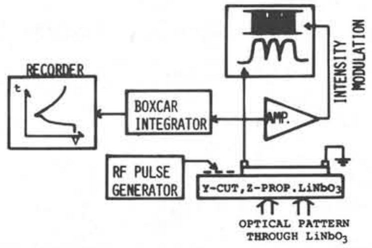

Fig.1 Experimental configuration.

Experimental & Discussion Figure 1 shows the experimental configuration. The half value width of the rf-pulse is 0.60μs, the interdigital transducer is 38μm in periodicity and has 8 finger pairs. The rf frequency is 95MHz. The peak wave lengths of the light source are 368, 407, 438, 494 and 548nm of a high pressure mercury lamp filtered with water saturated $CuSO_4$, and the total intensity is $1mW/mm^2$ on Ge surfaces. The most sensitive wave length is around 368nm where light illumination of $0.9\mu W/mm^2$ can strongly change the Vae signal as shown below. All experiments described here were carried out at room temperatures. Figure 2 shows the time dependence of spatial distribution of acoustoelectric voltage Vae of an n-type Ge before, under and after illumination. An example of intensity modulation pattern of an oscilloscope by Vae of a p-type Ge is shown in Fig.3. Figure 4 shows the time dependence of acoustoelectric voltage of an illuminated part for a p-type Ge. The memory time ranges usually from several minutes to more than half an hour, and half a day in some cases. The value of Vae after illumination is less or more than before illumination depending on the specimen, the illumination manner and especially on the acoustic power. The example of Vae increase by light illumination

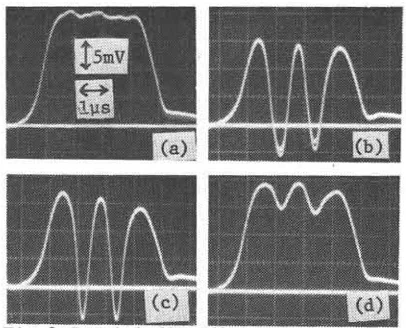

Fig.2 Spatial distribution of V_{ae}, two 0.75mm wide optical lines separated by 5mm on n-Ge No.4(7.8Ω·cm), (a) before illumination, (b) illuminated 3s, (c) 10s after illumination off, (d) 60s after illumination off.

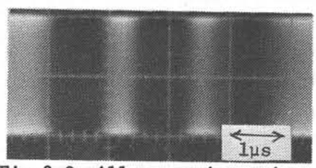

Fig.3 Oscilloscope intensity modulation by V_{ae} 180s after 3s-illumination off, using the same optical pattern as in Fig.2 and p-Ge No.2(9.1Ω cm).

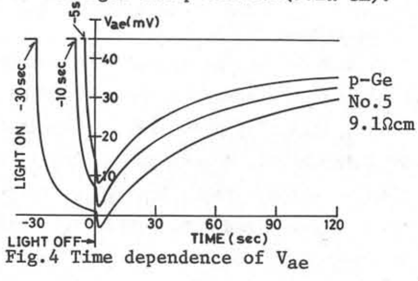

Fig.4 Time dependence of V_{ae}

is shown in Fig.5. The signs of the acoustoelectric voltages were positive for both n- and p-type Ge before illumination showing that the surfaces of Ge used are n-like due to the surface states. By the light illumination, the sign of Vae can be turned to negative. This p-like state is also due to the slow surface states as shown in the usual model of the Ge surface with an oxide layer in Fig.6. That is, when illuminated, the slow states capture electrons whose potential acts as a force which sweeps carrier electrons away from the surface. It should be emphasized that the image contrast between illuminated places and others can be easily made high and signal processings become easier when the Vae changes the sign. Fig.7 shows dependence of Vae on the light wave length using 5 peaks of the light source. Any slow response and long time memory effect could not be obtained when illuminated by a 1mW He-Ne laser at 632.8nm. The higher sensitive property at the shorter wave length is explained, by the model shown in Fig.6, as the light with energy higher than about 3eV can carry the valence electrons to the 'slow adsorption states' which can trap the electrons several days at 85K and about half an hour at room temperatures. It is pointed out from Fig.6 that the memorized signal can be erased by the light with the energy higher than 4eV. The half value width of the Vae dip by 0.75mm wide illumination is 0.64-0.73μs independent of time after illumination turned off. Take all experimental conditions into account the present spatial resolution is concluded to be limitted by the rf pulse width.

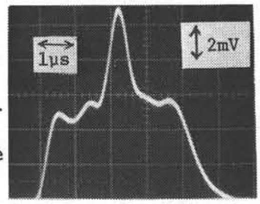

Fig.5 Example of V_{ae} increase. 4s after illumination off. p-Ge No.1 (9.1Ωcm)

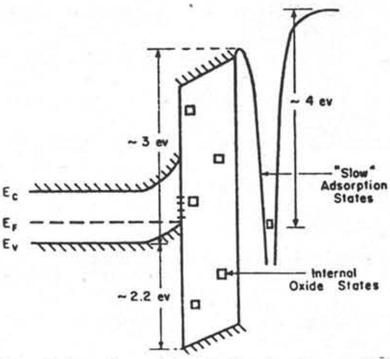

Fig.6 Usual model of Ge surface with an oxide layer. This figure is for p-type Ge with an accumulation space charge.

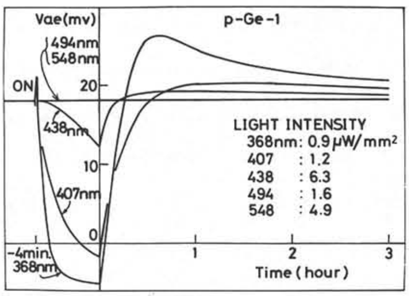

Fig.7 Light wave length dependence of V_{ae}. p-Ge No.1(9.1Ωcm).

All of the present effects can be explained by a simple model which is to be published later by the present authors. It is also possible to study semiconductor surfaces by this effect.

References

[1] S. Takada, H. Hayakawa and N. Mikoshiba, Appl. Phys. Lett. 23, 415 (1973).

[2] S. Takada, H. Hayakawa and N. Mikoshiba, Proceedings of Fifth Conference on Solid-State Devices, Tokyo, 1973 (Japan Soceiety of Applied Physics, Tokyo, 1974), p.194.

[3] T. Shiosaki, T. Kuroda and A. Kawabata, Appl. Phys. Lett. 26, 360 (1975).

[4] S.R. Morrison, Phys. Rev. 102, 1297 (1956).

[5] R.H. Kingston and A.L. McWhorter, Phys. Rev. 103, 534 (1956).

[6] S. Koc, Phys. Status Solidi 2, 1304 (1962).